BRECCIATED CHELYABINSK NEAR-EARTH ASTEROID AND ITS CATASTROPHIC AIR BURST.

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Introduction: Determining the hazards of near-Earth asteroid (NEA) impacts has been vexed by a paucity of precise data. Existing estimates of blast damage (e.g., [1]), for example, rely on uncertain impact energies for events like Sikhote-Alin, Tunguska, and Barringer Meteorite Crater. The Chelyabinsk air burst event of 15 February 2013, involving an LL-type NEA, provides an excellent calibration point for enhancing those assessments.

Chelyabinsk Air Burst: U.S. Government sensors indicate the impacting NEA had a velocity of 18.6 km/s and kinetic energy ~440 kt [2]. Using average bulk densities of LL-chondrite falls (3.22 g/cm^3) and S-class main belt asteroids (2.7 g/cm^3) [3], we derive an average diameter of 18.6 and 20 m, respectively. If the density was similar to that of rubble-pile LL-chondritic NEA Itokawa (1.9 g/cm^3 [4]) or rubble-pile binary NEAs (~1.5 g/cm^3), then the diameter may have been as large as 22 to 24 m.

We have previously argued that the strength of impacting NEA may be limited to structural flaws, like fractures and material contrasts (e.g., [5]. Fall phenomena support this concept; i.e., fragmental meteoroids preferentially produce meteorite showers [5]. Not surprisingly, Chelyabinsk is a brecciated LL-chondrite and cross-cut with impact melt veins that were generated by older collisional events. Impact-generated cataclasis produced a clast-supported breccia of light-colored chondrule-bearing clasts with sub-millimeter-wide fractures and silicate-rich shock melt veins, some of which form melt pockets where they intersect. Those clasts are separated by thin, sub-millimeter-wide channels of dark-colored matrix and centimeter-wide swaths of vesiculated and heterogeneously quenched impact melt.

Catastrophic fragmentation of these types of NEA can produce ground-level air blast effects if that fragmentation occurs at a sufficiently low altitude. Based on pre-Chelyabinsk scaling [5, 6], blast damage over an area of 10^2 to 10^3 km^2 is expected for a 440 kt event.

Collisional Evolution: The 20-meter-diameter Chelyabinsk meteoroid was composed of LL-type material, similar to that recovered from the 540-m-long Itokawa asteroid [7]. Both of those NEA were derived from one or more parent bodies >100 km diameter(s). Over 5,000 samples from an LL-chondrite parent body(ies) exist. Collisional events at 4.35-3.9 Ga are well-documented and several younger events have been suggested [8]. Whether one of those events or a separate event is responsible for the impact melt in Chelyabinsk is, as yet, unclear, but Ar-Ar analyses of the clasts and melt within Chelyabinsk are underway.

References: [1] Grieve R. A. F. and Kring D. A. 2007. *Comet/Asteroid Impacts & Human Society*, pp. 3–24. [2] http://neo.jpl.nasa.gov/news/fireball_130301.html. [3] Consolmagno G. J. et al. 2008. *Chemie der Erde* 68:1–29. [4] Fujiwara A. et al. 2006. *Science* 312:1330–1334. [5] Kring D. A. et al. 1996. *Journal of Geophysical Research* 101:29353–29371. [6] Toon O. B. et al. 1997. *Reviews of Geophysics* 35:41–78. [7] Nakamura T. et al. 2011. *Science* 333:1113–1116. [8] Swindle T. D. et al. 2013. In *^{40}Ar/^{39}Ar Dating: from Geochronology to Thermochronology, Archaeology to Planetary Science*, in press.